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This letter supplements the final report of August 1998 on Additional Objective: To Obtain the Structures of Asphalt Composite, which was part of the project Granular Materials Studied by MRI. We had our hydrogen-free bird cage coil rebuilt to get the background signal below that of the hydrogen in asphalt tar. We now present two images, one of tar in asphalt, one of SF6 gas in the proes of teh asphalt.
The asphalt came from Western Mobile Corporation, Albuquerque. We packed it, while hot, into a plastic syringe, to form a 2.5 cm diameter, 4 cm long cylindrical pellet. To image the pore spaces, we flushed the sample several times with SF6 gas, and then compressed the gas to approximately two atmospheres for imaging. To image the tar, we removed the sample from the syringe and supported it with a Teflon sheet to eliminate the syringe, which is easier to image than the tar in asphalt. Consistent with our experimence with other sand and gravel products, asphalt contains paramagnetic or ferromagnetic materials taht cause severe inhomogeneities in the magnetic field.

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2 April 1999

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ABS.

This letter supplements the final report of August 1998 on *Additional Objective: To Obtain the Structures of Asphalt Composite*, which was part of the project *Granular Materials Studied by MRI*. We had our hydrogen-free bird cage coil rebuilt to get the background signal below that of the hydrogen in asphalt tar. We now present two images, one of tar in asphalt, one of SF_6 gas in the pores of the asphalt.

The asphalt came from Western Mobile Corporation, Albuquerque. We packed it, while hot, into a plastic syringe, to form a 2.5 cm diameter, 4 cm long cylindrical pellet. To image the pore spaces, we flushed the sample several times with SF_6 gas, and then compressed the gas to approximately two atmospheres for imaging. To image the tar, we removed the sample from the syringe and supported it with a Teflon sheet to eliminate the syringe, which is easier to image than the tar in asphalt. Consistent with our experience with other sand and gravel products, asphalt contains paramagnetic or ferromagnetic materials that cause severe inhomogeneities in the magnetic field.

It was much easier to image the gas in the pores than to image the tar. The gas image (Figure 1a) required only 15 minutes for data collection. The short time was facilitated by the 3 ms T_1 of the fluorine signal, which allowed rapid signal averaging. We collected data for the tar image (Figure 1b) over 20 hours, although 5 hours would have provided an image with a signal-to-noise ratio comparable to the SF_6 image. The T_1 of the tar was about 0.5 seconds, and it gave less signal than the gas, perhaps because part of the tar's NMR signal decays too fast to be observed with the following methods.

We used spin echos, excited by 90° and 180° broadband pulses in the presence of constant 40 mT/m magnetic field gradients. The echo time was 300 microseconds, and the data sampling rate was 1 MHz. The 3D projection images were made using 138 different gradient directions with even angular distribution.

The tar signal and gas signal, without applied gradients, had bandwidths of 12 KHz and 7 KHz, respectively, so the inherent resolution of the images would have been roughly a centimeter. However, we enhanced the resolution by dividing each line of imaging data by the magnitude of the echo without applied gradients. The resulting resolution of the images is 2 mm.

One could achieve better results by using 100 mT/m gradients and sampling at 2 MHz or faster, or by using stray field imaging, as described in the previous report. Nonetheless, we have demonstrated that while imaging asphalt with NMR is difficult, it is possible to achieve separate images of the tar and gas spaces. With some additional improvements in equipment, one could

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achieve submillimeter resolution in 3D images. Furthermore, with improvements in sample and coil handling hardware, it would be possible to image the tar and the gas without moving the sample, allowing one to image the sand and gravel.

Sincerely,

Dean O. Kuethe Eiichi Fukushima

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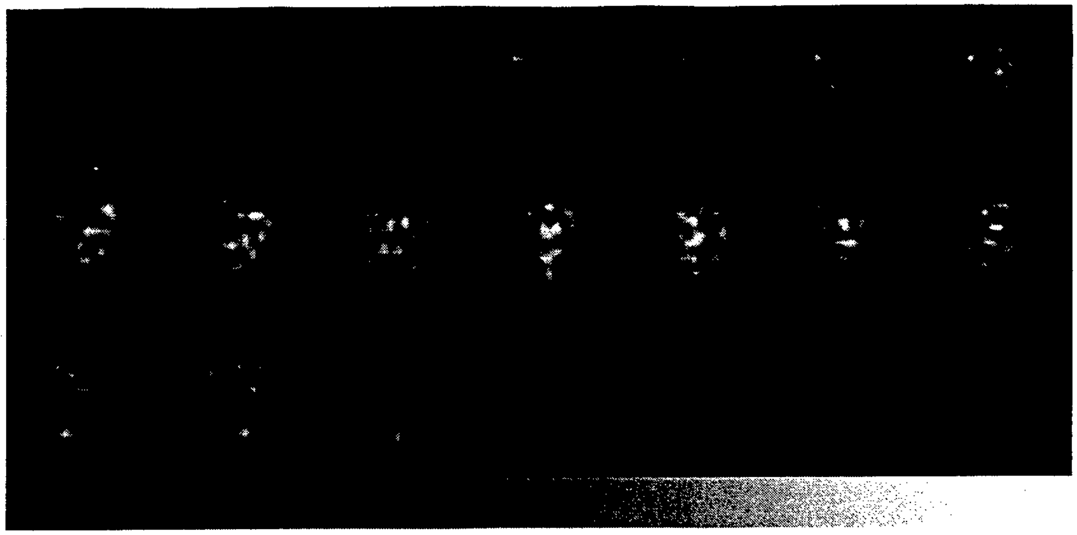
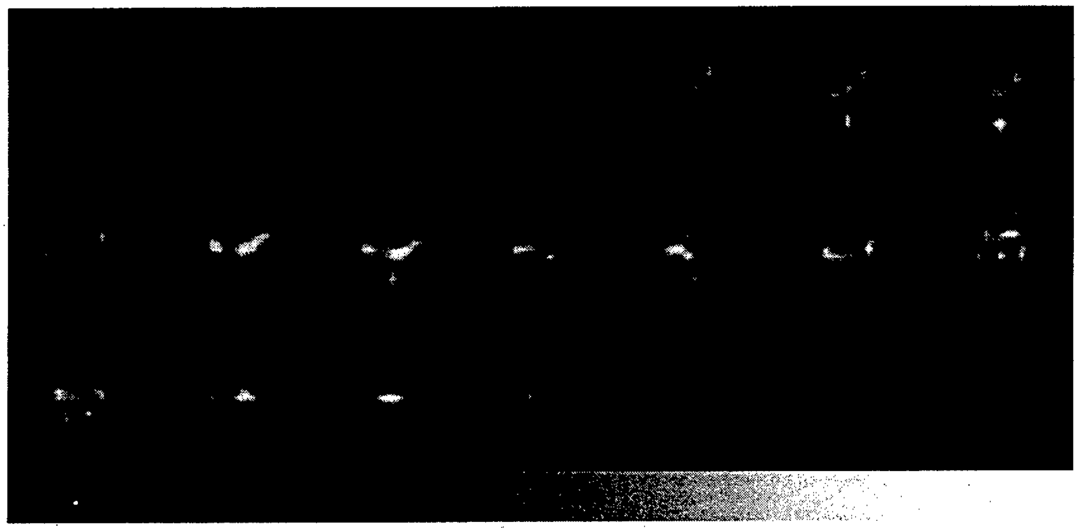


a Gas



b Tar

Figure 1. **a** Three-dimensional NMR image of SF_6 in the pores of a 2.5 cm dia., 4 cm long, cylindrical sample of asphalt. Twenty one consecutive *x-y* planes of the image are displayed from top left to bottom right. **b** a similar image of the tar in the same asphalt sample. Unfortunately, the sample is not oriented the same way in both images, so one can not satisfy the urge to find the sand and gravel, which were not imaged, by adding the two images.